Spatial and Temporal Observations of Summer Ice Melt Using ERS - 1 SAR imagery

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Abstract. This study examines the spatial and temporal character of ice melt. Using ERS-1 SAR imagery, we examine the development of small floes formed by melt and deformation, and changes in the fraction of open water, small floes and larger floes. We also examine the spatial variations in melt from the marginal ice zone up into the central Arctic ice pack. Results will provide initial estimates of the variation of melt rates and the relative importance of vertical and horizontal melt rates both spatially and temporally.

Introduction. The complete understanding of the heat and mass balance of the polar oceans includes the melting of sea ice in the summer and the reinfection of fresh water back into the upper ocean. Shortwave radiation provides the heat for thinning the ice through top and bottom ablation, lateral melt, and warming of the ocean. How the radiation is partitioned between vertical and horizontal melt is important since total heating of the upper ocean increases as ice concentration decreases (Figure 1) (Steele, 1992; Maykut and Perovich, 1987). The dynamic conditions and state of the summer ice cover significantly affects the thermodynamics of ice melt.

Sea ice melting is driven by a combination of the incident solar radiation, and the fracture of large floes into small floes by the passage of storms (Figure 2), While the radiation-driven melting proceeds slowly but continuously, the storm-driven fracture proceeds episodically, The storms break the large floes into small floes, which melt rapidly. The winds also roughen the open water, and increase its radar reflectivity, allowing us to use SAR for classification of a scene into three classes: open water, small, pixel-sized floes, and large floes. Given that these storms occur about 6-8 times during summer, we attempt to follow the evolution of the ice cover at approximately weekly intervals, and determine the changes in these ice and open water categories for different regions. These include the Chukchi Sea, which is a net ice sink, the Laptev Sea, a major ice source, and a predominantly multiyear ice region in the Beaufort Sea, Our goal will be to determine the melt rates on both the. large and small scale, and to estimate the fresh water flux to the upper ocean.

Current Study. To initiate our study on the measurement of floe size and open water concentration in the summer periods, we will test and compare several approaches. Due to summer melting of the. ice cover, the summer radar signatures of sea ice are reduced as compared to the winter signatures. These lower returns approach those of calm open water. A recent study has found that reliable measurements of open water are derived during days when the wind exceeds 4-5 m/s, which produce an open water SAR signature that is significantly higher than the ice returns (Comiso and Kwok, 1992).

For floe measurements, we must measure the relative. fraction of large floes and small, sub-pixel floes, as suggested by the results shown in Figure 2, and to measure the change in the floe size distribution and the increase in the number of small floes over summer. Using ERS - 1 SAR data, we are presently testing two methods for measurement of floe concentration and size.

The first method employs an algorithm developed at the University of Kansas (Haverkamp et al., 1995; Tsatsoulis, personal communication). This algorithm uses dynamic local thresholding, which identifies the number of classes in an image and automatically thresholds these classes. It is of particular value because it is insensitive to variations in intensity values within a class, such as is found in ocean and ice returns with varying incidence angles. The labeling of the classes is done with a knowledge-based method. Using summer data, tests show that one resulting class consists of the larger, darker floes, another is open water, and the remaining class is the sub-pixel size floes.

The second method consists of the measurement of the chord lengths of floes and/or leads from randomly oriented transects across a binary image (Lindsay and Rothrock, 1995). A floe or lead width is the length of the transect which is above or below a chosen threshold. The floe size distribution has been found to be well characterized by this technique (Rothrock and Thorndike, 1984). In summer, the binary image would require that the sub-pixel floes be placed in the open water class so as not to confuse the floe measurements. The open water fraction would then be measured radiometrically from its brightness.

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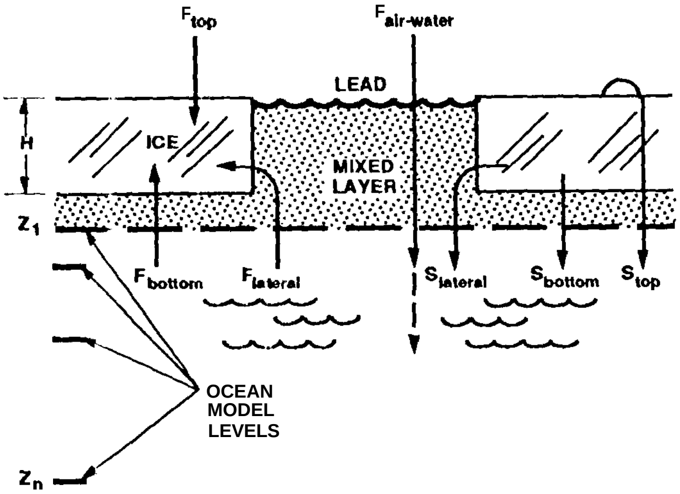

Figure 1. Ice-ocean model showing heat fluxes G and salt fluxes G during summer melt. The heat (salt) flux is positive (negative) in the direction of the arrows. After Steele (1992) and Maykut and Perovich (1987).

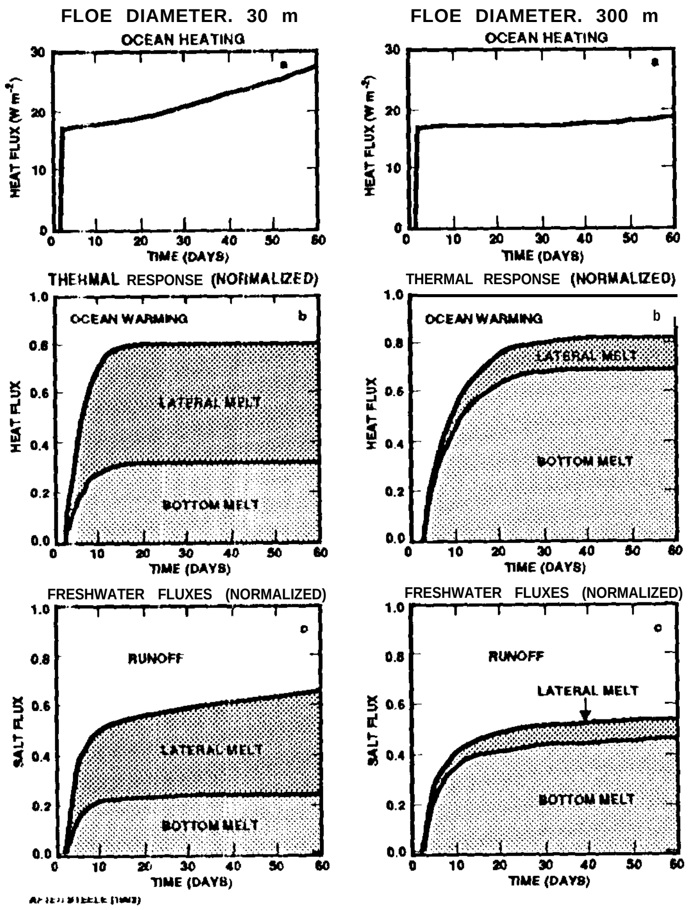

Figure 2. Ocean heat and salt budgets during summer melt for initial floe diameter of 30 m (left) and 300 m (right). After Steele (1992).